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COST EFFECTIVENESS OF CUSHIONING MATERIALS FOR FAST
PACKS(U) AIR FORCE PACKAGING EVALUATION AGENCY
WRIGHT-PATTERSON AFB OH MATERIALS ENGINEERING BRANCH

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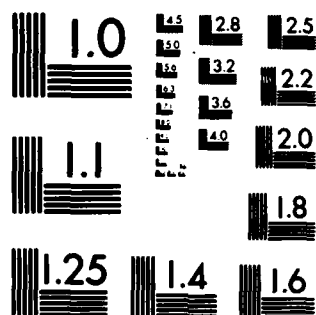
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COST EFFECTIVENESS OF CUSHIONING MATERIALS FOR FAST PACKS

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HQ AFLC/DSTZT
Air Force Packaging Evaluation Agency
Wright-Patterson AFB OH 45433

JANUARY 1984

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ABSTRACT

Consideration of potential cost savings as well as material availability problems resulted in the initiation of a study by this agency to reevaluate the polyurethane foam cushioning requirements specified in the Fast Pack specification PPP-B-1672. Additional emphasis was given to this study when the AFLC Spares Packaging Standardization Committee established and assigned an action item to AFPEA to determine whether the Grade C polyurethane foam currently specified for Fast Pack cushion inserts could be replaced with Grade B material which was less expensive and easier to obtain commercially. An extensive test program was conducted on the Type I, III, and IV Fast Packs in which the dynamic cushioning performance of both Grade B and C polyurethane cushion inserts were evaluated over the weight ranges currently specified in Appendix G of MIL-STD-794 for several of the different pack sizes. It was concluded that the substitution of Grade B polyurethane foam for Grade C foam could not be justified because of the significant reduction in the range of items that could be adequately protected.

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INTRODUCTION

This study was performed primarily to support the HQ AFLC/DSTP Spares Packaging Standardization Committee's effort to resolve shortages of fast pack containers reported throughout DOD. In addition AFPEA recognized the potential for reducing the cost of fast packs by substituting the less expensive Grade B polyurethane foam cushioning for the Grade C materials currently used. The shortage of fast packs stemmed from commercial manufacturers' difficulty in readily producing Grade C polyurethane foam meeting the dynamic cushioning characteristics specified in MIL-P-26514E. Consequently, the committee questioned whether Grade C foam as required in Federal Specification PPP-B-1672 for Type I, III and IV fast pack inserts was cost effective for the shock protection levels specified in Appendix G of MIL-STD-794D (Fast Pack Selection). It was noted that Grade B polyurethane foam, if used as an alternative, would cost less and would be more readily available from a larger number of manufacturers. The objective of this study was to determine if the proposed alternative Grade B polyurethane foam would provide protection comparable to that now obtained with the Grade C material.

EQUIPMENT AND INSTRUMENTATION

Evaluation of the fast packs and polyurethane foams used in the cushion inserts were performed with the following equipment and instrumentation:

1. Container drop tester, Gaynes, Model 125 DTP.
2. Cushion tester, Hardigg Industries, Model 3.
3. Compression - Tensile tester, Instron TT-C.
4. Three Endevco crystal accelerometers, Model 2233E.
5. Three Endevco charge amplifiers, Model 2614C.
6. Endevco power supply, Model 2622C.
7. Tektronix four trace storage oscilloscope, Type 564B.
8. Statham strain gage accelerometer, Model A5-100-350.
9. GHI Energy Computer, Model EC700.
10. Sensotac power amplifier.

TEST LOADS

The prototype test loads (Figures 3 & 4) consisted of interchangeable wood, aluminum, lead and steel plates for the purpose of varying the weight. Each prototype load was instrumented with three crystal accelerometers, triaxially mounted at the center of gravity of the test load. The prototype loads were wrapped with 3 mil thick polyethylene film to reduce the friction between the load and cushion pad surfaces in order to avoid interference with the cushioning action of the polyurethane pads.

DESCRIPTION OF TEST PACKS

The exterior containers were fabricated from V3c corrugated fiberboard regular slotted containers conforming to specification PPP-B-636. The cushioning inserts in the pack were Type I, Class 2, Grade B and C, 1.5 pound density polyurethane foam meeting the dynamic cushioning properties specified in MIL-P-26514E. The type and size packs tested are identified in Figures 5 through 18. The fast packs were acquired from various air logistics center locations sampled from unused General Services Administration supply lots.

TEST PROCEDURES

Drop testing of Type I, III and IV fast packs containing Grades B and C polyurethane inserts, was performed during this study. The results obtained on these fast packs were then used to develop comparative Peak "G" - static stress curves depicted in Figures 5 through 18.

A. Fast pack drop tests: Free fall drop tests were conducted in accordance with procedure B, Method 5007 of Federal Test Method Standard 101C, Level A (30-inch drop). Testing began with the lightest weight prototype loads and progressed to successively heavier weight loads. For each weight of prototype load five drops were made on each of the container's six faces. The drops were alternated between opposite side faces or opposite end faces, so that no face received two successive impacts. The peak G shock resultants for the end face impacts were averaged together for each load of a particular configuration; the same procedure was used for averaging the peak G shock resultants for the four side faces.

B. Dynamic compression test of polyurethane foam cushion insert materials: The dynamic compression test of the polyurethane foam used in the fast packs was in accordance with paragraph 4.5.3.13 of MIL-P-26514E. Following completion of the fast pack drop testing, cushioning inserts (usually end pads) were removed from the containers and allowed to recover over a 72-hour period. Following the recovery period, three 8" x 8" x 3" specimens from each cushioning insert were cut and cyclically compressed ten times to 65 percent of their original thicknesses on an Instron compression tester. Inserts having convoluted surfaces (Type III fast packs) were cut flush and laminated with double face adhesive tape to make three-inch thick specimens. Following a 16 to 72-hour recovery period, the specimens were tested on the cushion drop tester. Each specimen was impacted by the drop platten of the cushion tester which compressed the specimens at an initial velocity of 136 ± 2 in/sec (24-inch drop height). The acceleration-time record of the impact was displayed on the CRT of the oscilloscope and the peak G values were measured and recorded for each drop. With drop platten weight at the lowest static stress value, five drops were made on each specimen allowing at least one minute between drops. Additional weight was added to the drop platten to obtain higher static stress points and the drop test procedure was repeated. Four static stress points (0.065, 0.15, 0.4, 0.8 psi) were selected to fully cover the range of the Grade B and C dynamic cushioning curves depicted in MIL-P-26514E. Peak acceleration values (Gs) within ± 20 percent of specification curve were considered as acceptable for verifying the material as either Grade B or Grade C polyurethane foam.

RESULTS

Based on the test results presented in Figures 5 through 18, it is apparent that Fast Packs utilizing Grade B foam will not provide the required shock protection over the entire weight ranges for Grade C foam specified in MIL-STD-794. It is estimated that Grade B foam inserts provided acceptable shock protection over only 61 percent of the weight ranges considered in Appendix G of MIL-STD-794. The reduced cushioning performance of Grade B foam in most cases was attributed to increased shock inputs occurring with the heavier items due to "bottoming out" of the cushion during repeated impacting.

DISCUSSION/CONCLUSIONS

Grade B foam Fast Pack inserts would afford shock protection levels equivalent to Grade C foam inserts over approximately 61 percent of the weight ranges currently specified in MIL-STD-794. This reduced effectiveness is considered to be contrary to the original purpose of the Fast Pack Program of providing optional shock protection to a maximum number of the diverse items in the DOD inventory.

The implementation of Grade B foam inserts into the Fast Pack Program would require retention of Grade C foam packs in the system to protect those items not afforded adequate protection by the Grade B foam. At least ten of the fourteen types sizes of Grade C foam packs evaluated would probably have to be retained to complement the Grade B foam packs. This could result in redundancy in design and possible confusion resulting in the use of the wrong pack for an item.

Based on a survey of the major manufacturers of polyurethane foam it was determined that on average there is a 8.1 percent mark up in the cost of Grade C material over Grade B. During a one-year period approximately 3,000,000 board feet of Grade C polyurethane foam at a total cost of \$600,000 are used in the manufacture of Fast Packs for the Air Force. Therefore the substitution of Grade B for Grade C foam would result in a savings of \$45,000, assuming these savings are passed on to the government. It is believed that these savings are far outweighed by the potential consequences of replacing a proven pack with a less effective one which could result in damage to high value Air Force equipment.

Another consequence of introducing Grade B foam materials into the Fast Pack system would be the time, effort, and expense required to revise the Fast Pack selection tables in MIL-STD-794. Revision of these tables would require further extensive drop testing to develop complete data for all Type I, III and IV Fast Packs.

RECOMMENDATIONS

It is recommended that Grade C polyurethane foam requirement be continued for Type I, III and IV Fast Packs.

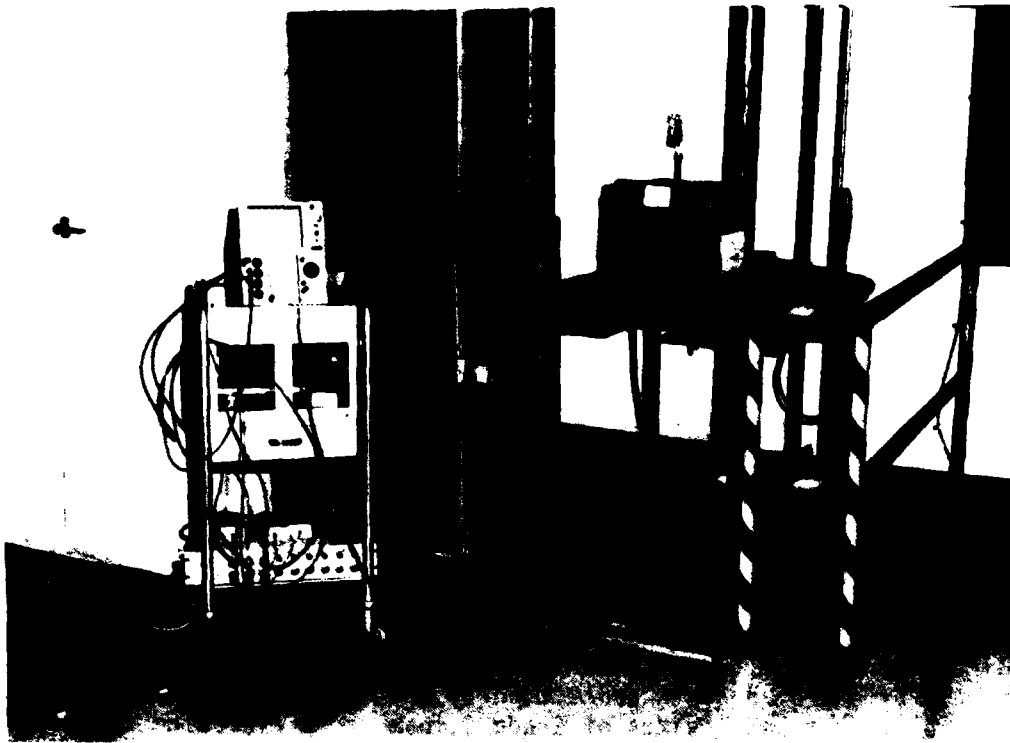


FIGURE 1. GAYNES DROP TESTER AND INSTRUMENTATION

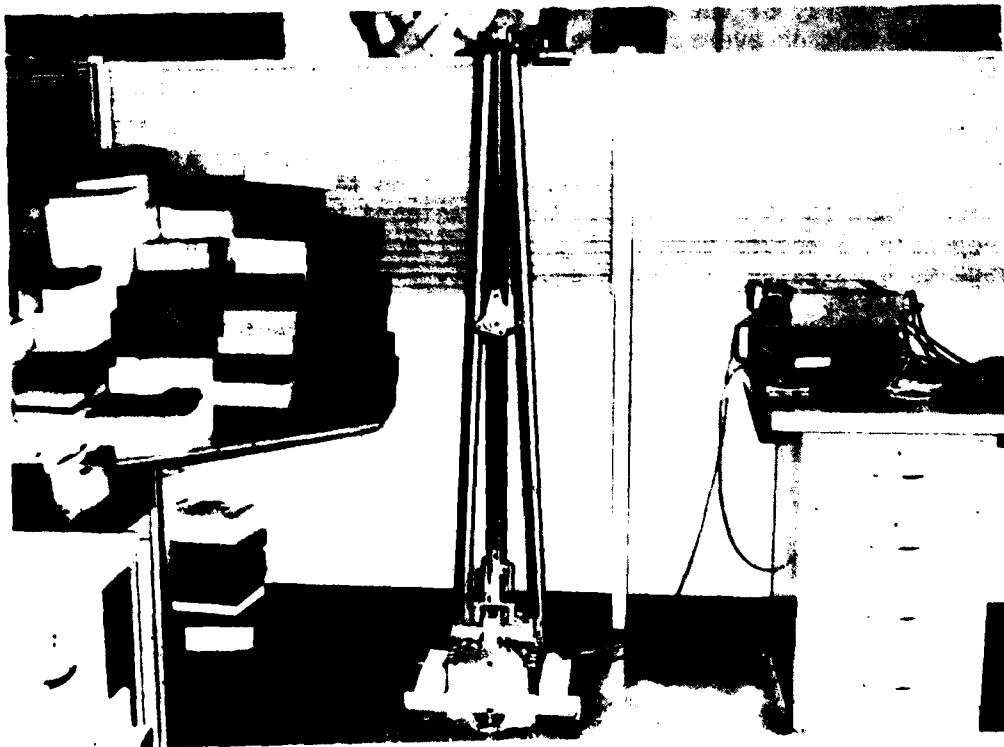


FIGURE 2. HARDIGG CUSHIONING TESTER AND INSTRUMENTATION



FIGURE 3. TYPICAL TEST LOADS USED IN TYPE I AND II FAST PACKS

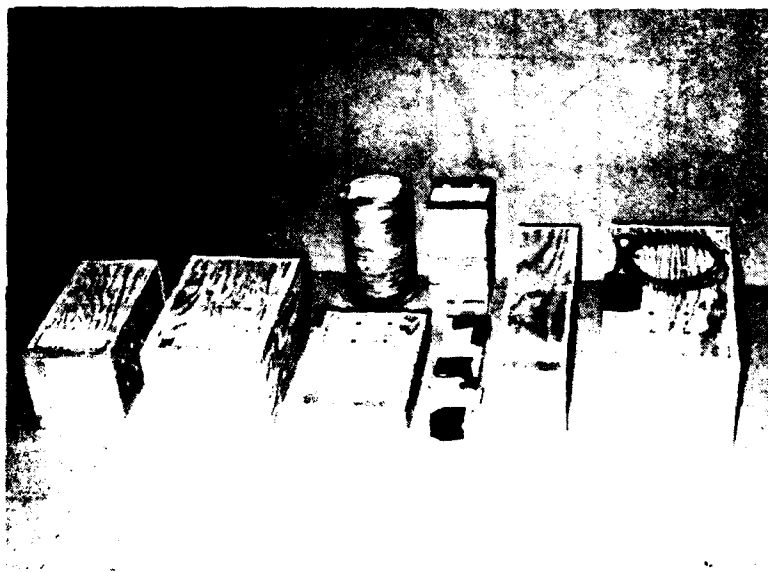
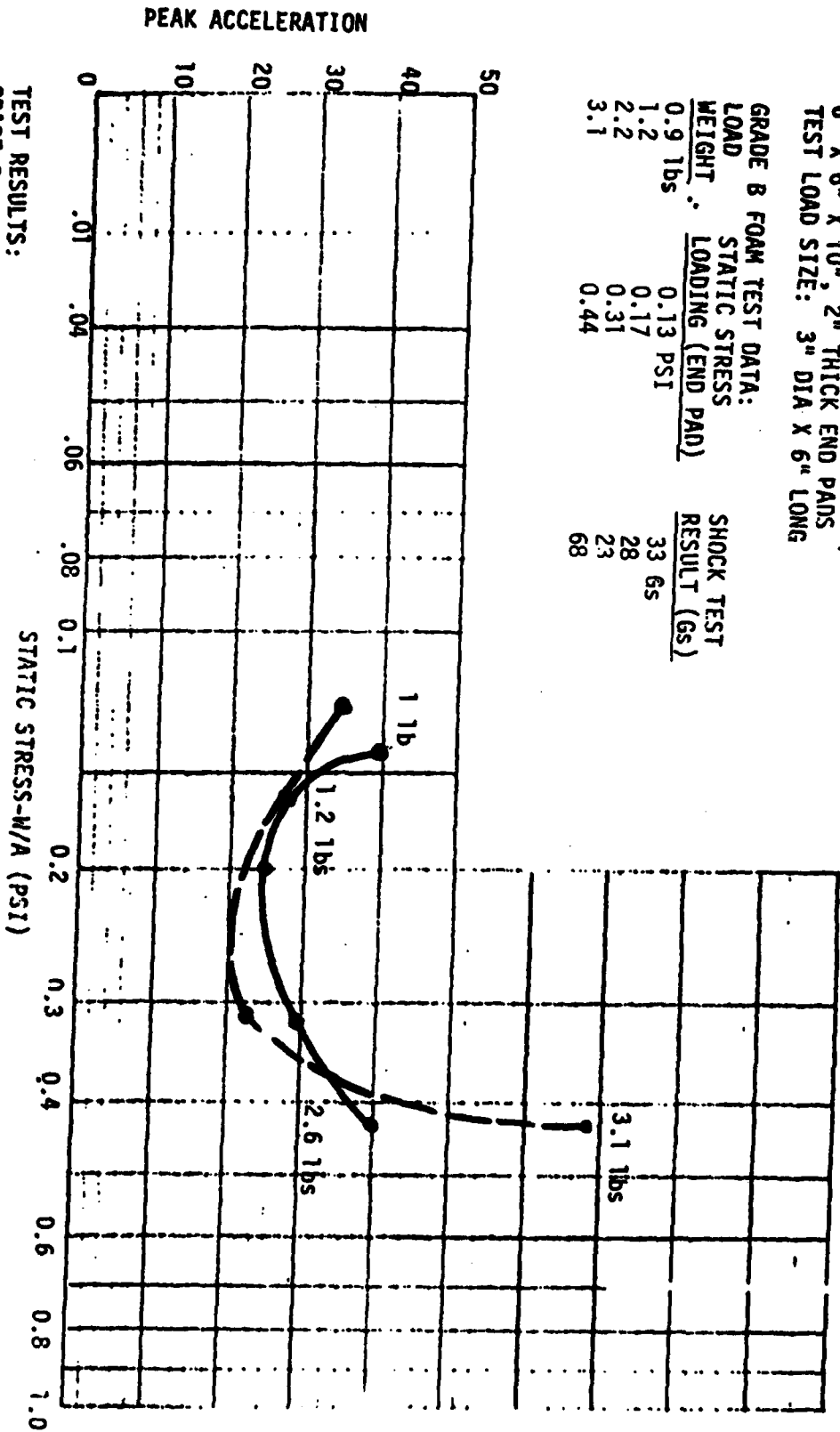


FIGURE 4. TYPICAL TEST LOADS USED IN TYPE IV FAST PACKS

FIGURE 5.

FAST PACK TYPE I. (VERTICAL STAR)
6" X 6" X 10", 2" THICK END PADS
TEST LOAD SIZE: 3" DIA X 6" LONG

GRADE B FOAM TEST DATA:		
LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULT (Gs)
0.9 lbs	0.13 PSI	33 Gs
1.2	0.17	28
2.2	0.31	23
3.1	0.44	68



TEST RESULTS:

GRADE B FOAM EXCEEDED THE SHOCK LEVEL FOR WEIGHT RANGE 2.7-3.1 lbs. SPECIFIED IN MIL-STD-794. HOWEVER, FOR LOADS WEIGHING 1 TO 2.6 lbs, IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

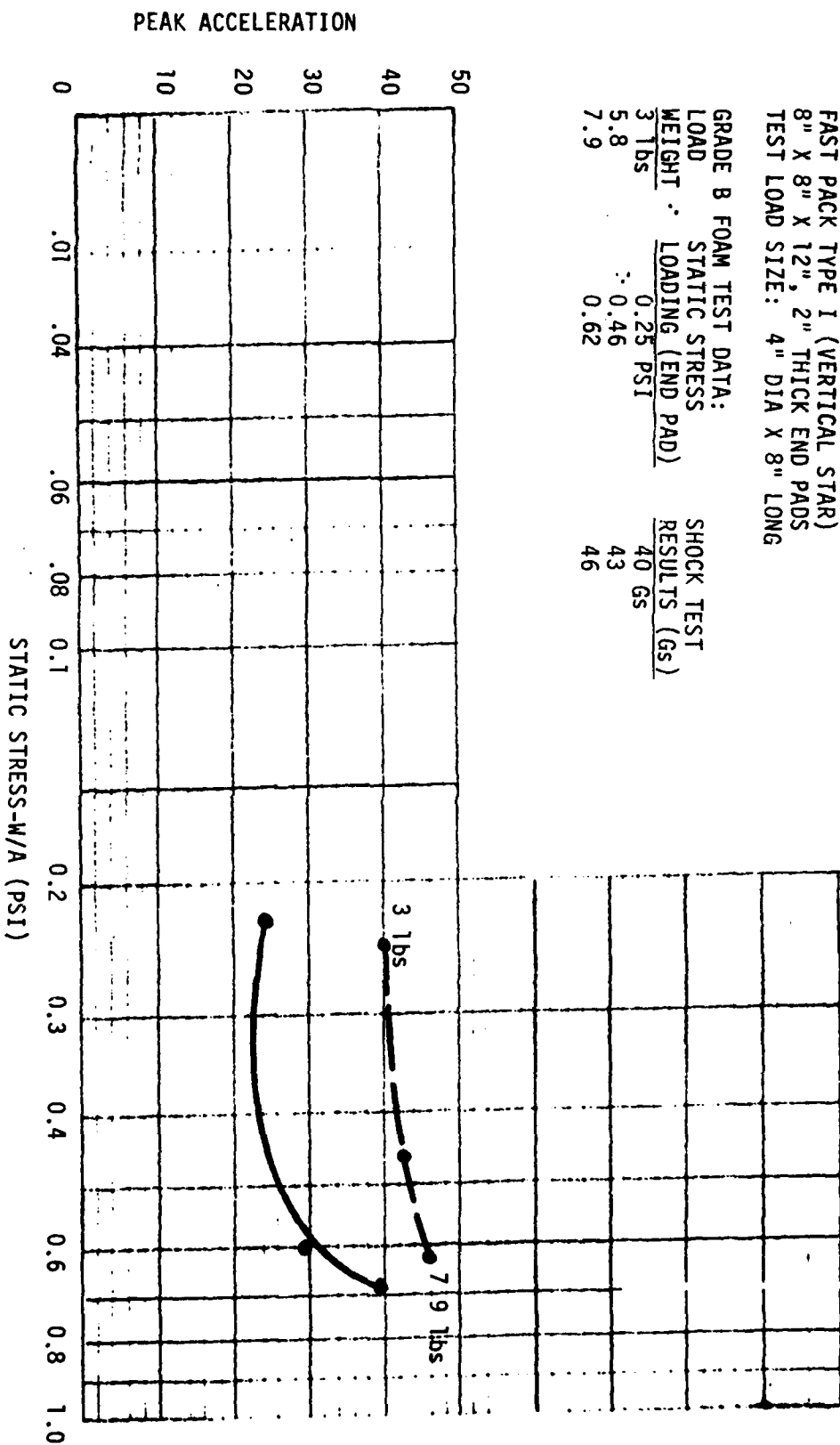
LEGEND:

-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
____GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 6

FAST PACK TYPE I (VERTICAL STAR)
8" X 8" X 12", 2" THICK END PADS
TEST LOAD SIZE: 4" DIA X 8" LONG

GRADE B FOAM TEST DATA:		
LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULTS (Gs)
3 lbs	0.25 PSI	40 Gs
5.8	0.46	43
7.9	0.62	46



TEST RESULTS:
GRADE B FOAM SHOCK LEVEL EXCEEDED THOSE OF GRADE C FOAM OVER THE FULL ITEM WEIGHT
RANGE 3 TO 7.9 LBS.

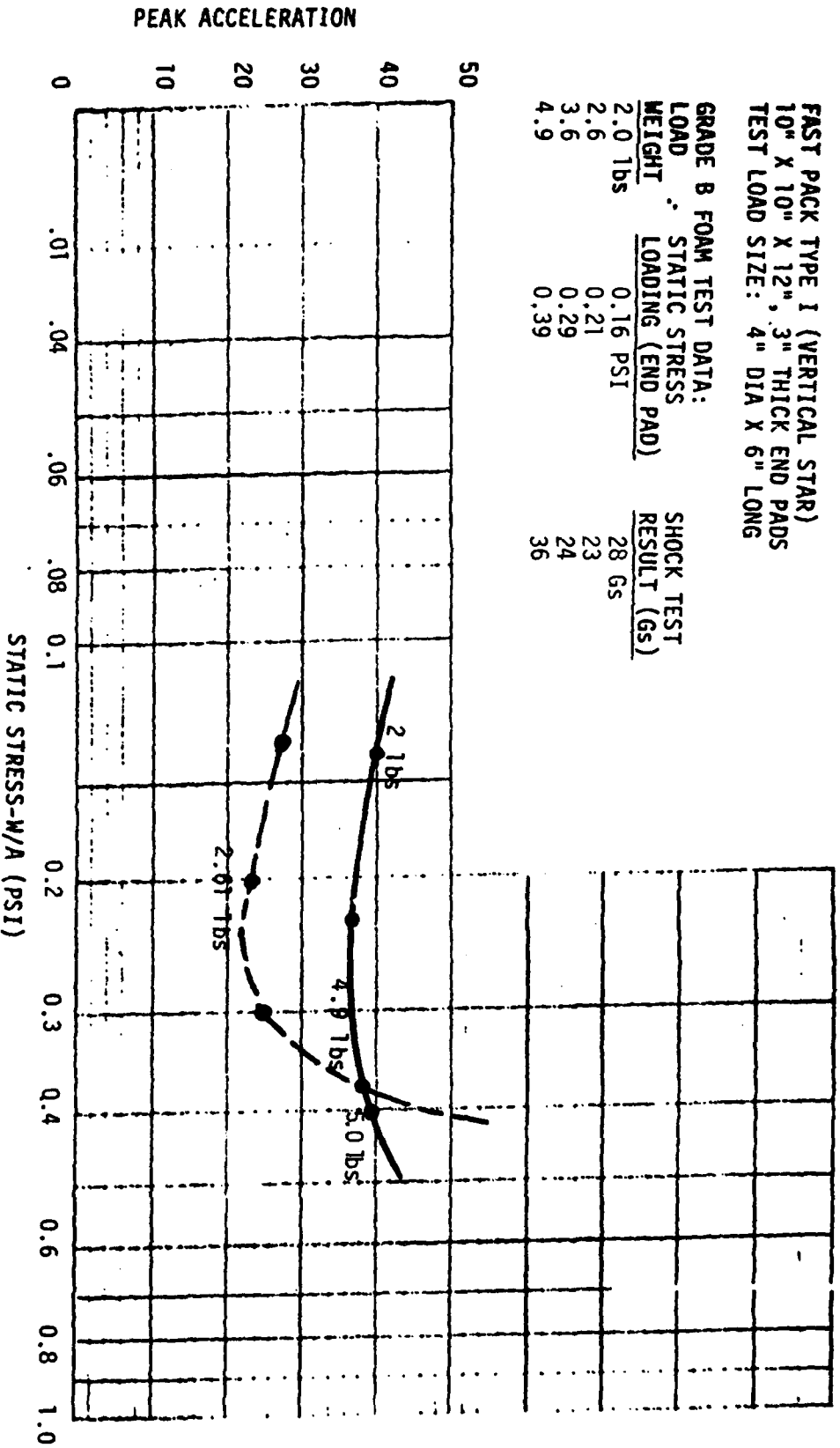
LEGEND:
----- GRADE "B" FOAM SHOCK PROTECTION LEVELS
----- GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 7

FAST PACK TYPE I (VERTICAL STAR)
10" X 10" X 12", 3" THICK END PADS
TEST LOAD SIZE: 4" DIA X 6" LONG

GRADE B FOAM TEST DATA:

LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULT (Gs)
2.0 lbs	0.16 PSI	28 Gs
2.6	0.21	23
3.6	0.29	24
4.9	0.39	36



TEST RESULTS:
GRADE B FOAM PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS OVER THE 2 - 4.9 LB WEIGHT RANGE; HOWEVER, IT EXCEEDED THE SHOCK PROTECTION LEVEL OVER WEIGHT RANGE 4.9 TO 5.0 LBS.

LEGEND:

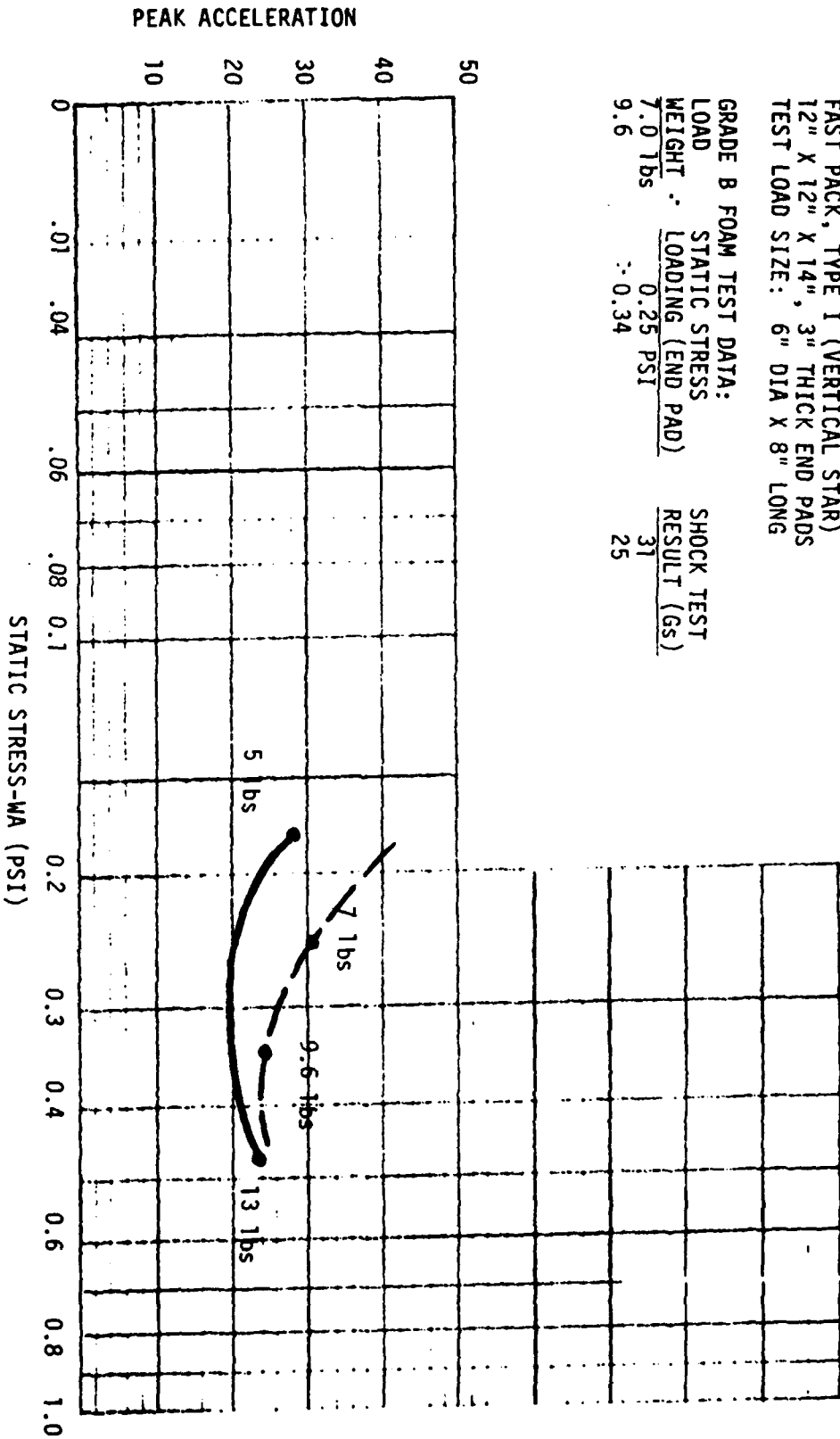
----- GRADE "B" FOAM SHOCK PROTECTION LEVELS
----- GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 8

FAST PACK, TYPE I (VERTICAL STAR)
12" X 12" X 14", 3" THICK END PADS
TEST LOAD SIZE: 6" DIA X 8" LONG

GRADE B FOAM TEST DATA:

LOAD	STATIC STRESS	SHOCK TEST
WEIGHT	LOADING (END PAD)	RESULT (Gs)
7.0 lbs	0.25 PSI	31
9.6	0.34	25



TEST RESULTS:

GRADE B FOAM SHOCK LEVEL EXCEEDED THOSE OF GRADE C FOAM OVER THE FULL ITEM WEIGHT RANGE 5 TO 13 LBS

LEGEND:

----- GRADE "B" FOAM SHOCK PROTECTION LEVELS
_____ GRADE "C" FOAM SHOCK PROTECTION LEVELS

**FAST PACK TYPE I (VERTICAL STAR)
12" X 12" X 14", 3" THICK END PADS
TEST LOAD SIZE: 5" DIA X 8" LONG**

GRADE B FOAM TEST DATA:

LOAD	STATIC STRESS	SHOCK TEST
WEIGHT	LOADING (END PAD)	RESULT (Gs)
3.4 lbs	0.17 PSI	21 Gs
6.6 lbs	0.34	29

12" X 12" X 14", 3" THICK END PADS
TEST LOAD SIZE: 5" DIA X 8" LONG

PEAK ACCELERATION

Static Stress-W/A (PSI)	Peak Acceleration (Gs)	Weight (lbs)
0.17	21	3.4
0.34	29	6.6
0.17	21	3.5
0.34	29	8.5

STATIC STRESS-W/A (PSI)

TEST RESULTS:
GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER THE ITEM WEIGHT RANGE 4.4 TO 8.5 LBS; HOWEVER FOR LOADS WEIGHING 3.5 TO 4.0 LBS IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

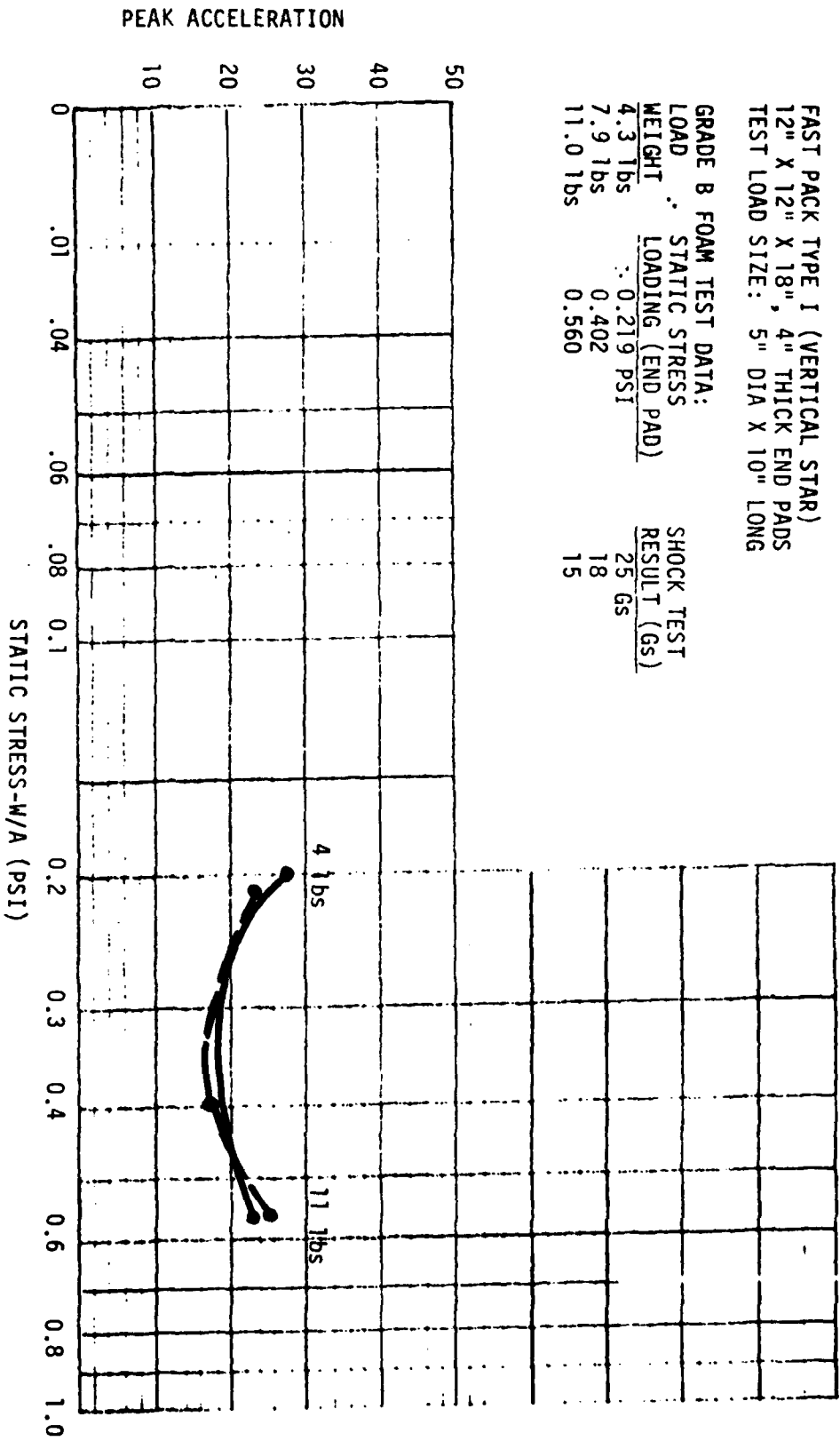
LEGEND:

GRADE "B"	FOAM SHOCK PROTECTION LEVELS
GRADE "C"	FOAM SHOCK PROTECTION LEVELS
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
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85	85
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89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

FIGURE 10

FAST PACK TYPE I (VERTICAL STAR)
12" X 12" X 18", 4" THICK END PADS
TEST LOAD SIZE: 5" DIA X 10" LONG

GRADE B FOAM TEST DATA:		
LOAD	STATIC STRESS	
WEIGHT	LOADING (END PAD)	SHOCK TEST
4.3 lbs	0.219 PSI	25 GS
7.9 lbs	0.402	18
11.0 lbs	0.560	15



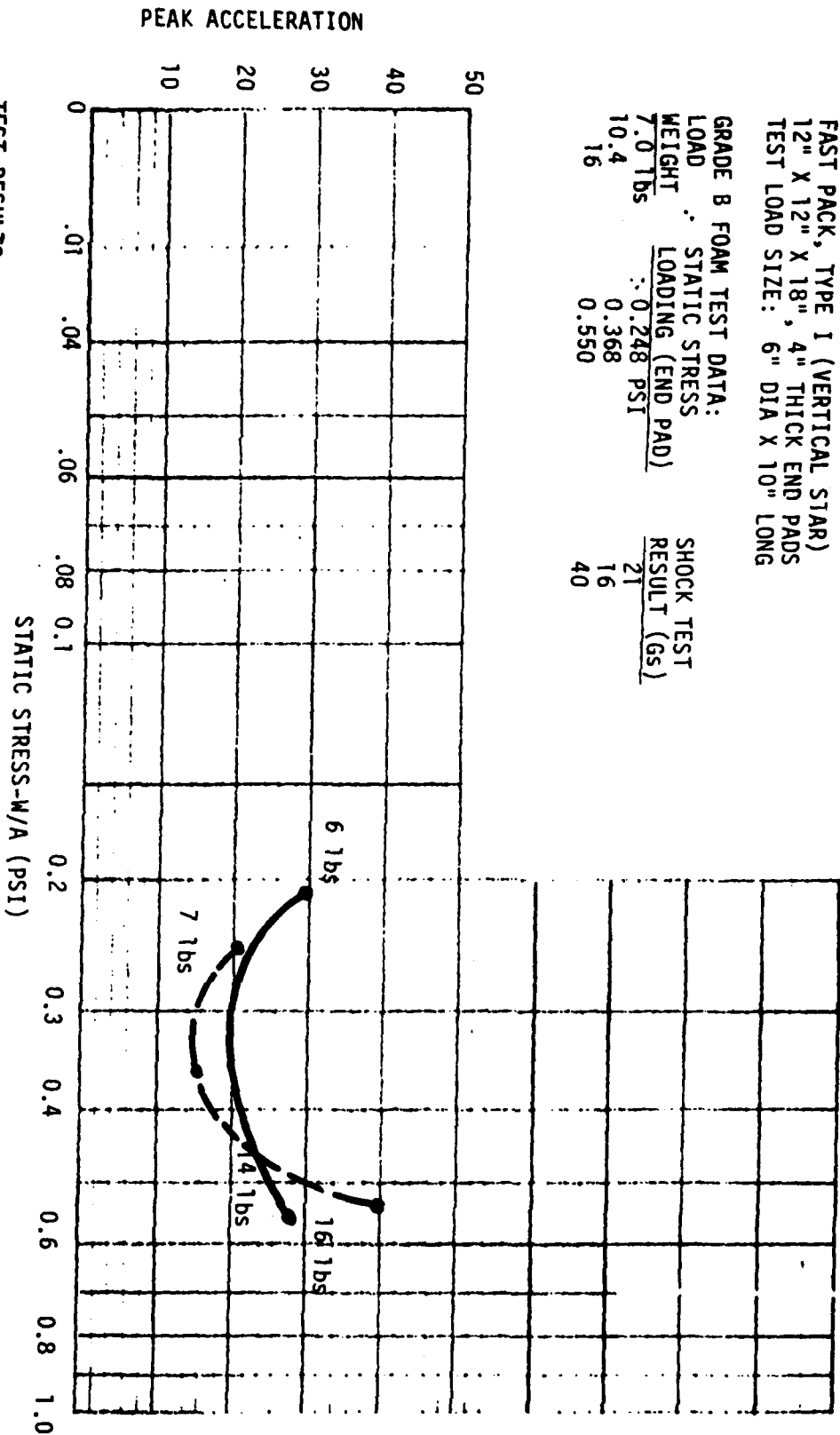
TEST RESULTS:
GRADE B FOAM PROVIDED EQUIVALENT SHOCK PROTECTION LEVELS OVER THE FULL ITEM WEIGHT RANGE 4 TO 11 LBS.

LEGEND:
-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
-----GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 12

FAST PACK, TYPE I (VERTICAL STAR)
12" X 12" X 18", 4" THICK END PADS
TEST LOAD SIZE: 6" DIA X 10" LONG

GRADE B FOAM TEST DATA:		
LOAD	STATIC STRESS	
WEIGHT	LOADING (END PAD)	
7.0 lbs	0.248 PSI	
10.4	0.368	
16	0.550	
		SHOCK TEST
		RESULT (Gs)
		21
		16
		40



TEST RESULTS:

GRADE B FOAM PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS OVER THE ITEM WEIGHT RANGE 7 TO 14 LBS;
HOWEVER IT EXCEEDED THOSE SHOCK LEVELS OVER THE WEIGHT RANGE 14.1 TO 16 LBS

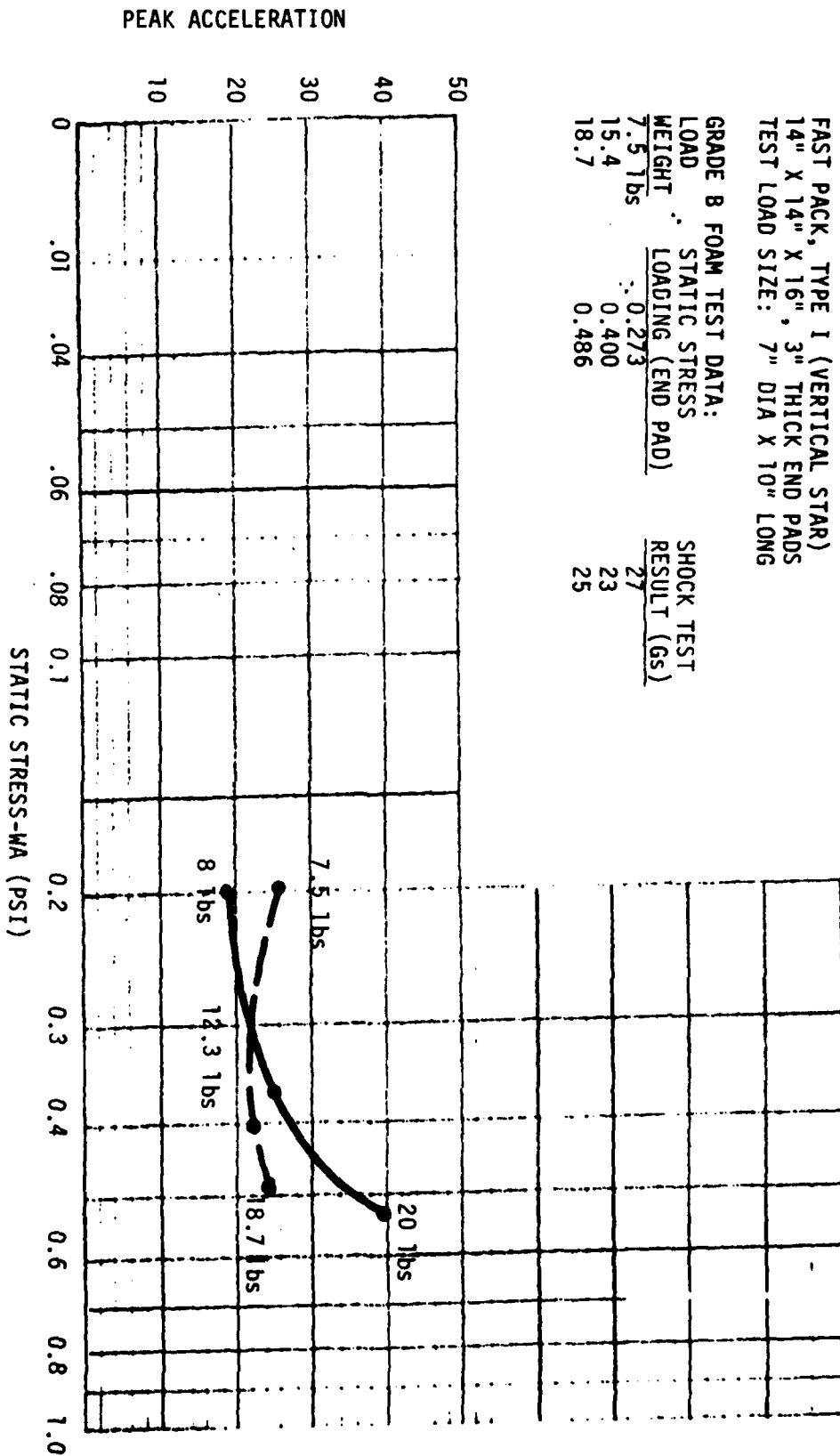
LEGEND:

GRADE "B" FOAM SHOCK PROTECTION LEVELS
GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 11

FAST PACK, TYPE I (VERTICAL STAR)
14" X 14" X 16", 3" THICK END PADS
TEST LOAD SIZE: 7" DIA X 10" LONG

GRADE B FOAM TEST DATA:		
LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULT (Gs)
7.5 lbs	0.273	27
15.4	0.400	23
18.7	0.486	25



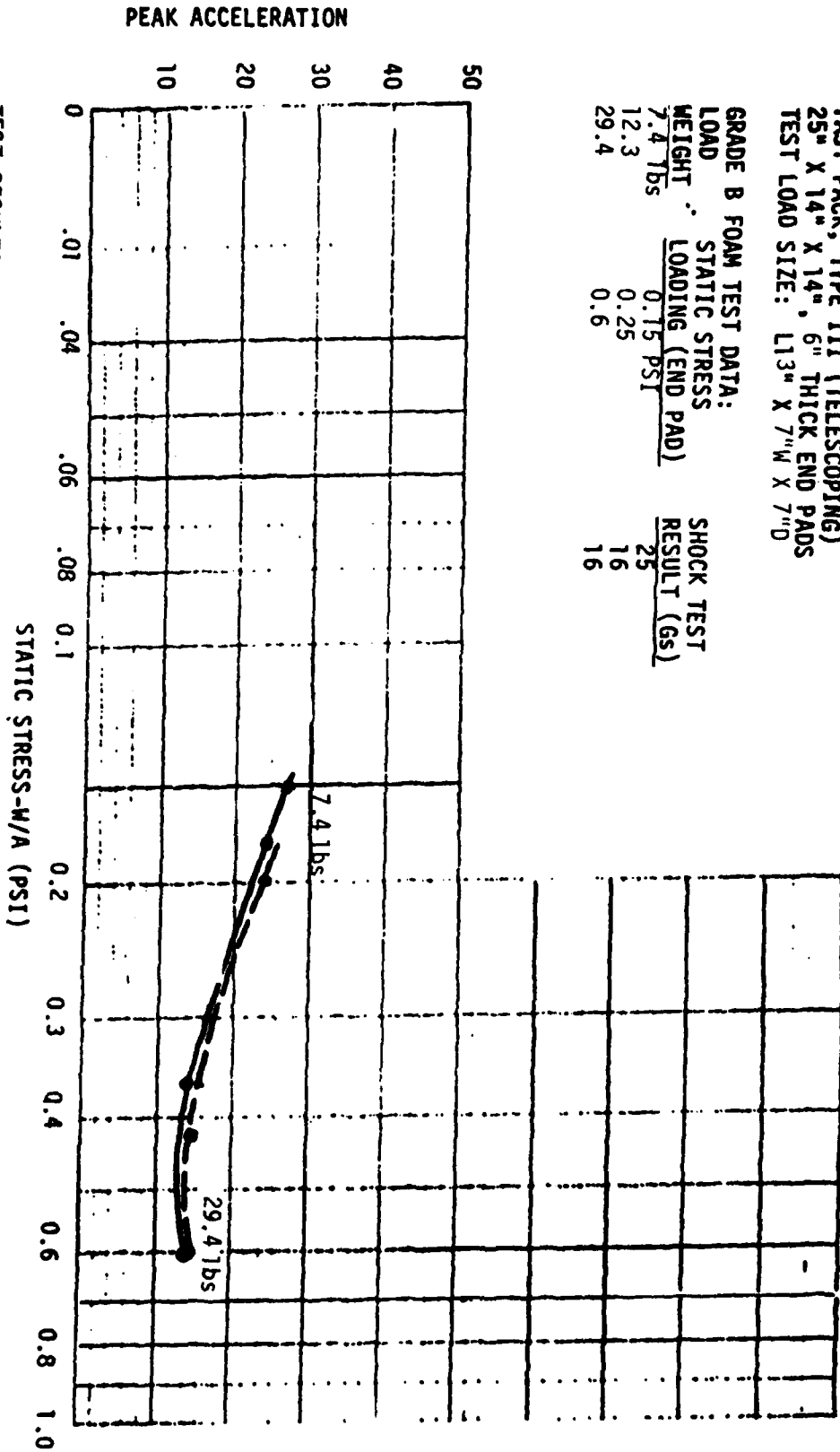
TEST RESULTS:
GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER THE ITEM WEIGHT RANGE 7.5 TO 12.4 LBS; HOWEVER, FOR LOADS WEIGHING 12.3 TO 20 LBS, IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

LEGEND:
-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
-----GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 13

FAST PACK, TYPE III (TELESCOPING)
25" X 14" X 14", 6" THICK END PADS
TEST LOAD SIZE: L13" X 7" W X 7" D

GRADE B FOAM TEST DATA:		
LOAD	STATIC STRESS	
WEIGHT	LOADING (END PAD)	SHOCK TEST
7.4 lbs	0.15 PSI	25
12.3	0.25	16
29.4	0.6	16



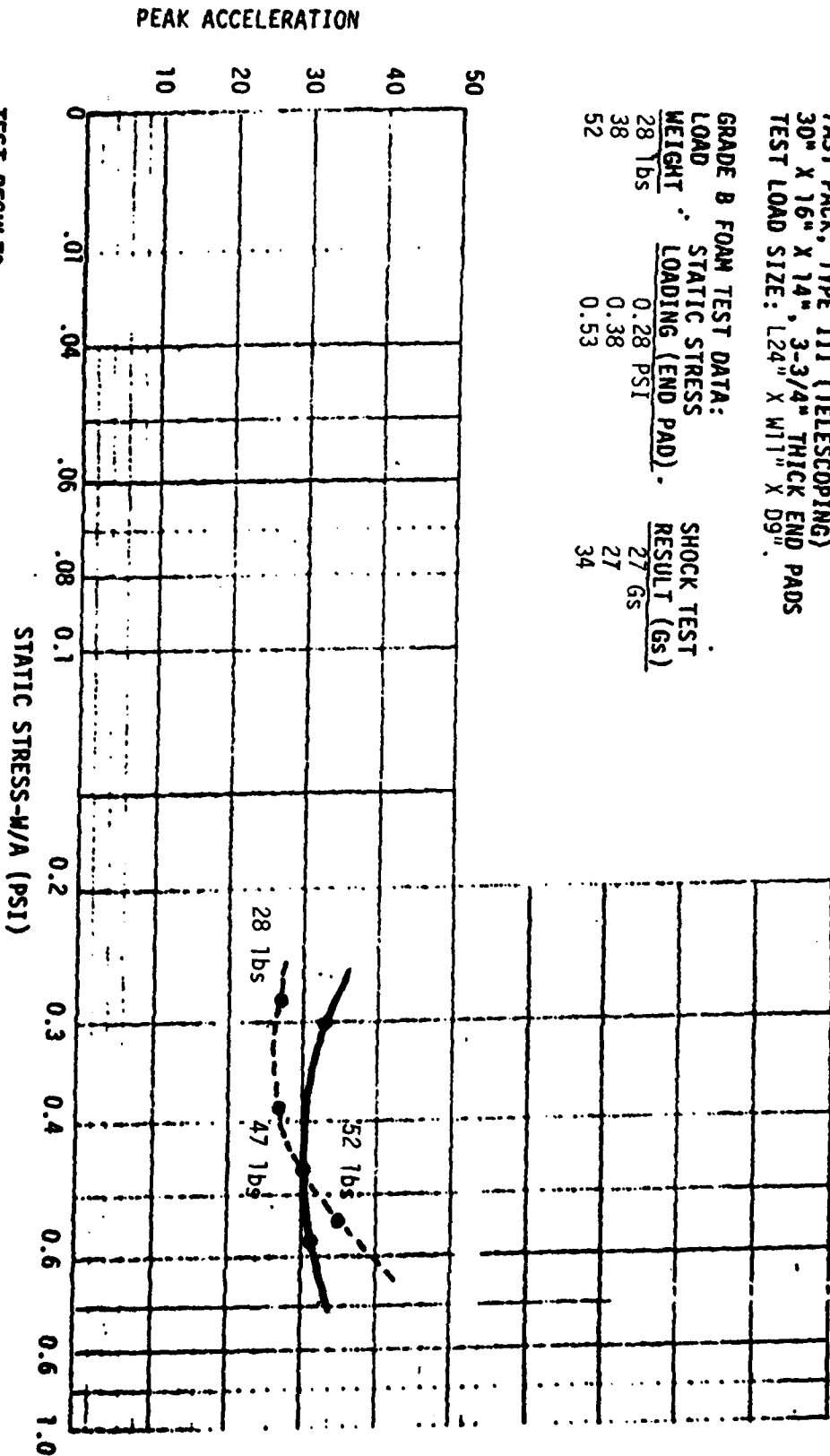
TEST RESULTS:
GRADE B FOAM PROVIDED EQUIVALENT SHOCK PROTECTION LEVELS OVER THE FULL RANGE
7.4 TO 29.4 LBS.

LEGEND:
----- GRADE "B" FOAM SHOCK PROTECTION LEVELS
----- GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 14

FAST PACK, TYPE III (TELESCOPING)
30" X 16" X 14", 3-3/4" THICK END PADS
TEST LOAD SIZE: L24" X W11" X D9"

GRADE B FOAM TEST DATA:		
LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULT (Gs)
28 lbs	0.28 PSI	27 Gs
38	0.38	27
52	0.53	34



TEST RESULTS:

GRADE B FOAM PROVIDED EQUAL OR BETTER SHOCK PROTECTION OVER THE WEIGHT RANGE 28 - 47 LBS; HOWEVER FOR LOADS ABOVE 47 LBS IT EXCEEDED GRADE C FOAM SHOCK LEVELS.

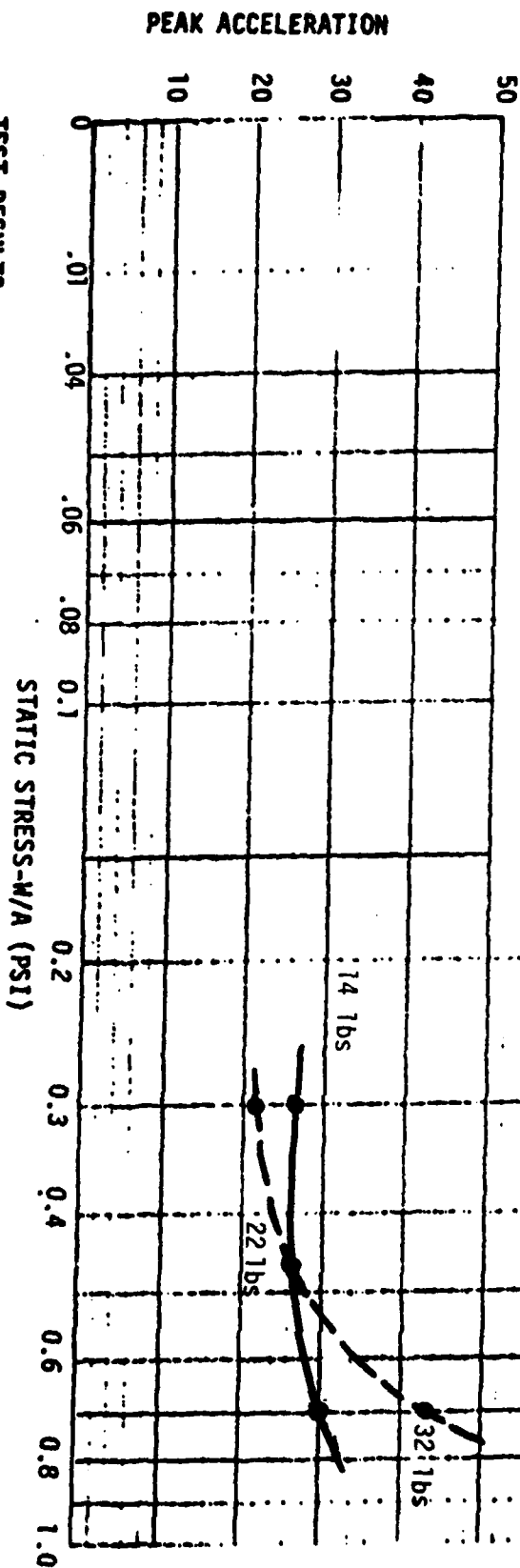
LEGEND:

GRADE "B" FOAM SHOCK PROTECTION LEVELS
GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 15

FAST PACK, TYPE 111 (TELESCOPING)
32" X 12" X 14", 4" THICK END PADS
TEST LOAD SIZE: 24" X 6" X 8"

GRADE B FOAM TEST DATA:		
LOAD WEIGHT	STATIC STRESS LOADING (END PAD)	SHOCK TEST RESULT (Gs)
14 lbs	0.3 PSI	22 Gs
22	0.46	27
32	0.67	40



TEST RESULTS:

GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER THE ITEM WEIGHT RANGE 22 TO 32 LBS; HOWEVER, FOR LOADS WEIGHING 14 TO 22 LBS, IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

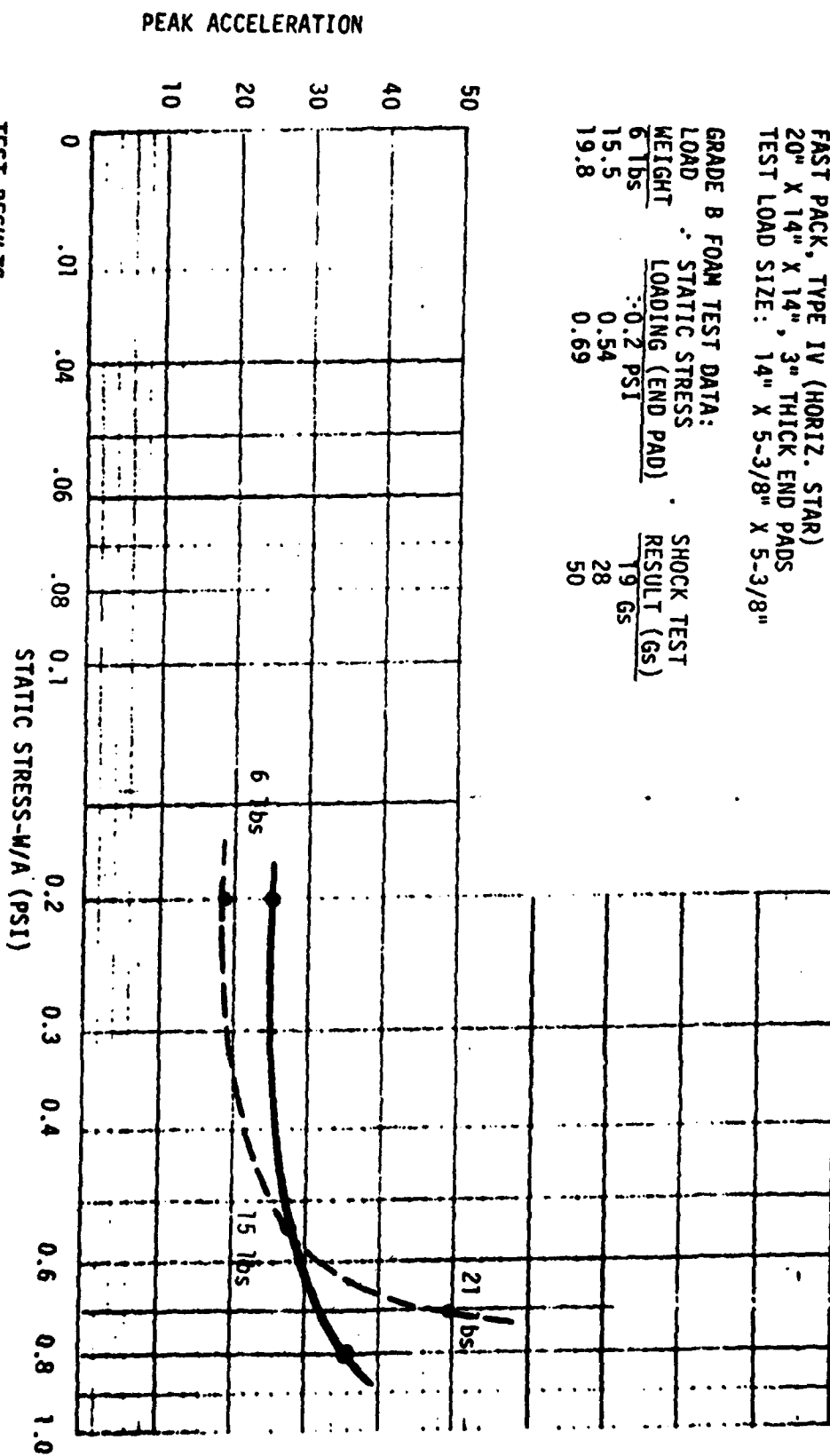
LEGEND:

-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
-----GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 16

FAST PACK, TYPE IV (HORIZ. STAR)
20" X 14" X 14", 3" THICK END PADS
TEST LOAD SIZE: 14" X 5-3/8" X 5-3/8"

GRADE B FOAM TEST DATA:			
LOAD	STATIC STRESS		
WEIGHT	LOADING (END PAD)		SHOCK TEST
6 lbs	0.2 PSI		RESULT (Gs)
15.5	0.54		28
19.8	0.69		50



TEST RESULTS:

GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER THE ITEM WEIGHT RANGE 15.5 TO 21 LBS; HOWEVER, FOR LOADS WEIGHING 6 TO 15.5 LBS, IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

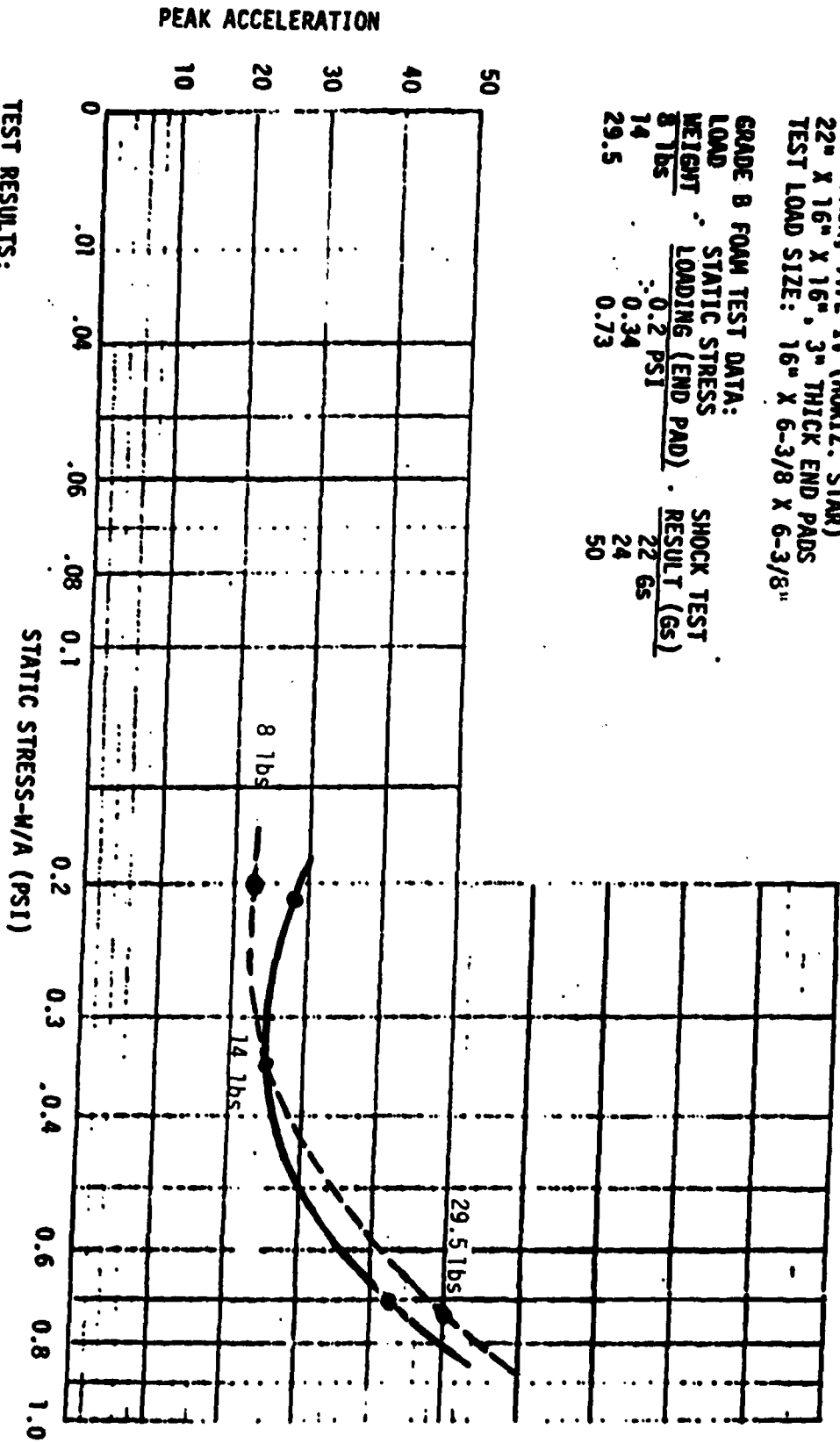
LEGEND:

----- GRADE "B" FOAM SHOCK PROTECTION LEVELS
----- GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 17

FAST PACK, TYPE IV (HORIZ. STAR)
22" X 16" X 16", 3" THICK END PADS
TEST LOAD SIZE: 16" X 6-3/8 X 6-3/8"

GRADE B FOAM TEST DATA:		
LOAD	STATIC STRESS	
WEIGHT	LOADING (END PAD)	SHOCK TEST
8 lbs	0.2 PSI	RESULT (Gs)
14	0.34	22
29.5	0.73	24
		50



TEST RESULTS:

GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER ITEM WEIGHT RANGE ABOVE 14 TO 29.5 LBS; HOWEVER, FOR LOADS WEIGHING 14 TO 8 LBS, IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

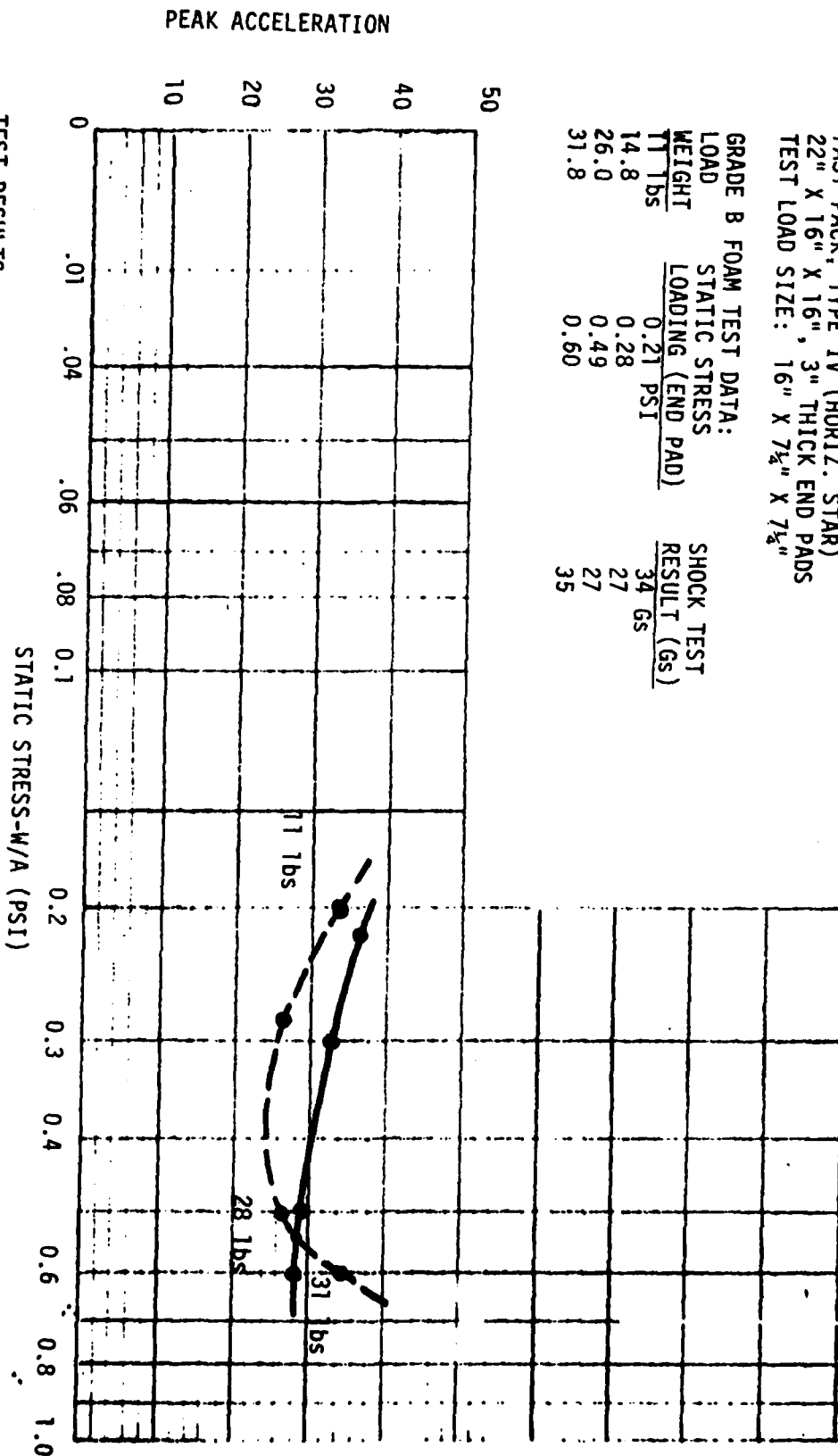
LEGEND:

-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
-----GRADE "C" FOAM SHOCK PROTECTION LEVELS

FIGURE 18

FAST PACK, TYPE IV (HORIZ. STAR)
22" X 16" X 16", 3" THICK END PADS
TEST LOAD SIZE: 16" X 7 1/4" X 7 1/4"

GRADE B FOAM TEST DATA:		
LOAD	STATIC STRESS	
WEIGHT	LOADING (END PAD)	SHOCK TEST
11 lbs	0.21 PSI	RESULT (Gs)
14.8	0.28	34 Gs
26.0	0.49	27
31.8	0.60	27
		35



TEST RESULTS:

GRADE B FOAM EXCEEDED THE SHOCK PROTECTION LEVELS OVER ITEM WEIGHT RANGE 28 TO 31 LBS; HOWEVER, FOR LOADS WEIGHING 11 TO 28 LBS IT PROVIDED EQUAL OR BETTER SHOCK PROTECTION LEVELS.

LEGEND:

-----GRADE "B" FOAM SHOCK PROTECTION LEVELS
-----GRADE "C" FOAM SHOCK PROTECTION LEVELS

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Consideration of potential cost savings as well as material availability problems resulted in the initiation of a study by this agency to reevaluate the polyurethane foam cushioning requirements specified in the Fast Pack specification PPP-B-1672. Additional emphasis was given to this study when the AFLC Spares Packaging Standardization Committee established and assigned an action item to AFPEA to determine whether the Grade C polyurethane foam currently specified for Fast Pack cushion inserts could be replaced with Grade B material which was less expensive and easier to obtain commercially. An extensive test program was conducted on the Type I, III, and IV Fast Packs in which the dynamic cushioning performance of both Grade B and C polyurethane cushion inserts were evaluated over the weight ranges currently specified in Appendix G of MIL-STD-794 for several of the different pack sizes. It was concluded that the substitution of Grade B polyurethane foam for Grade C foam could not be justified because of the significant reduction in the range of items that could be adequately protected.					
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